Impacts of Climate Change and Variability on Smallholder Dairy Cattle Production in Bungoma, Kenya

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Abstract: Climate change is becoming one of the most serious challenges to Kenya's achievement of its development goals as described under Vision 2030. Kenya is already highly susceptible to climate-related hazards, and in many areas, extreme events and variability of weather are now the norm; rainfall is irregular and unpredictable; while droughts have become more frequent during the long rainy season and severe floods during the short rains. Dairy farming is highly sensitive to climate change and variability, and rain-fed agriculture systems, in particular, are especially susceptible to unpredictable weather. Agricultural production is intricately linked to animal feed provision and hence, small holder dairy herd productivity. Small holder dairy farming faces a high risk of reduced productivity resulting from extreme weather occasioned by climate change and weather variability. Therefore this study sought to determine the impacts of climate change and variability on smallholder dairy cattle production in Bungoma, Kenya. Data were analyzed using both quantitative and qualitative data analyses approaches. Quantitative approach was descriptive, where frequencies and percentages were used. Correlation analysis was conducted to show the relationship between rainfall (mm), temperature (oC), dairy cattle population and milk production (kgs.) in Mt. Elgon, Tongaren and Kimilili sub counties. The finding indicates that there was decreasing acreage under fodder and pasture production. Farmers owned less than 5 dairy cows that produced a daily average of 5-8 litres and 2-5litres per cow during the wet and the dry season respectively. During the dry season, farmers used preserved feed, crop residues or feeds purchased from neighbours. While the tick borne diseases, pneumonia and lumpy skin incidences had increased in the county, foot and mouth disease had decreased during the past ten years. Extreme weather changes especially dry spell was associated with increased incidences of tick borne and Foot and Mouth diseases, shortage of feed resources and reduced milk production in the three study sites. Changes in climatic patterns especially the decreasing dry spell, droughts, and unpredictable precipitation has contributed to increased livestock diseases incidences such as East coast fever, foot and mouth diseases, shortage of feed resources hence, increased cost of food and feeds, and overall reduction of milk production in the Bungoma County. Therefore, there existed a significant relationship between the changing climatic patterns and smallholder dairy herd productivity in the county. Climate change and variability effects are on great increase and quickly eroding the gains of dairy technologies adapted in the recent times in the county to boost smallholder dairy cattle production in the county. The study recommends on both policy formulation and investment adaptations by the county government to address to minimize losses and damages incurred by smallholder dairy cattle farmers, occasioned by increased frequency of extreme rainfall over the three sites.

Key words: *Climate Change, Variability, Smallholder Dairy Cattle, Bungoma County, Kenya*

1. Introduction

Dairy farming is highly sensitive to climate change and variability, and rain-fed agriculture systems, in particular, are especially susceptible to unpredictable weather. Agricultural production is intricately linked to animal feed provision and hence, small holder dairy herd productivity as discussed by Volenzo (2013). Kenya has a long tradition in dairy production which was mainly non-commercial milk production from the indigenous cattle (zebu). The commercial dairy industry in Kenya dates back to 1920 when white settlers imported purebred dairy cattle from Europe. The commercial dairy farming developed in two distinct phases. Firstly, large-scale dairy farming that was on farms operated by Europeans on the Kenyan Highlands; and secondly from the 1950's on African smallholdings (Ishaya & Abaje, 2018). It is, therefore, important to evaluate the impact of climate change on smallholder dairy herd productivity in Bungoma County which strives to reduce poverty levels and prevalent food insecurity situation in the current climate.

Climate change is becoming one of the most serious challenges to Kenya's achievement of its development goals as described under Vision 2030. Kenya is already highly susceptible to climate-related hazards, and in many areas, extreme events and variability of weather are now the norm; rainfall is irregular and unpredictable; while droughts have become more frequent during the long rainy season and severe floods during the short rains. The climate is changing and that this change is different from natural variability. They identified variation in rainfall patterns reflected by a change in distribution, duration, and amount of rains as the key indicator of climate change; participants also cited temperature change, but less often, with most farmers referring to an increase in temperature (Ishaya & Abaje, 2018).

In Kenya, climate change and variabilty are evidenced by irregular and un-predicrainfall, intense downpours, rising temperature and generally extreme and harsh weather (GOK, 2018). Since the 1960s both minimum and maximum temperatures have been on an increase or warming trend (GOK, 2018). The maximum temperature has generally risen by O.7-2°C and the minimum by 0.2-1.3 ° C depending on region and season (GOK, 2018). Western Kenya has had an increase in temperature of 0.8 -2.9 °C (GOK, 2018). Total annual precipitation projection in the country suggest an increase of approximately 0.2- 0.4 per cent per year (NCCRS, 2010). The country experienced major droughts every decade and minor ones every three to four years (Mutimba et al, 2010; NCCRS, 2010; KMD, 2018). The change in climate has a mainly adversarial impact upon agricultural production because it affects climatic factors such as temperature and precipitation (Muchemi 2015; Barasa et al., 2015).

Small holder dairy farming faces a high risk of reduced productivity resulting from extreme weather occasioned by climate change and weather variability. Overall, dairy products yields may fall by 10 to 20% to 2050 because of warming and drying, but there are places where yield losses may be much more severe as indicated in the Agricultural Sector Development Support Programme (ASDSP) Report (Bungoma County Government, 2014). The annual milk production is estimated at 97 Million litres, and is mainly produced in the upper sub-Counties of this County mainly Tongaren, Kimilili and Mt. Elgon (Bungoma County Government, 2018). Bungoma County is food insecure and also records a poverty index of 52.9% compared to the National index of 46%, while the food insecurity stands at 43%, KNBS (2010). Many families in the County take one meal a day, in contrast to the recommended three meals per day (UNICEF, 2019).

With the fast-growing demand for milk and other dairy products resulting from increasing population and urbanisation, the dairy industry in Bungoma has great potential to enhance the generation of household income mainly among smallholder farmers as well as to create employment opportunities for the local population. Livestock and in particularly dairy farming is critical in the county with income generated from the sale of dairy products and livestock accounting for about 31% of the total household income Bungoma County Government (2018). Among other challenges facing the smallholder dairy in Bungoma County are climate change and

variation related that have contributed to the high cost of dairy cattle herd production. The low dairy herd productivity in East Africa is attributed to limited use of production technologies and inadequate exploitation of the existing environmental influences. Mapiye *et al.* (2016) alluded that the low quantity and quality of feed resources affected the productivity of dairy animals in sub-Saharan Africa. It is because of the above that the current study sought to evaluate the impact of climate change and variability on smallholder dairy cattle production in Bungoma, Kenya.

2. Literature Review

In Bungoma County, the annual milk production is estimated at 97 Million litres, and is mainly produced in the upper sub -Counties of this County mainly Tongaren, Kimilili and Mt.Elgon. The livestock sector in Bungoma County comprises the following sub sectors; dairy, poultry, beef pig, sheep and goat, beekeeping, rabbit, emerging livestock and donkey production Bungoma County Government (2015). Dairying refers to rearing of dairy animals purposely for milk production with the main aim selling milk to the consumer (IDF, 2014).

Animal products contribute substantially in stabilizing the food security trend in the rural poor for their daily survival (Van jink & Wilkes, 2015). From exotic breeds totalling 129,000 and with 30% in lactation, Bungoma County produces 270,900 litres of milk daily with another production of 75,795 litres daily from the zebu breeds.

Dairy farming is vulnerable to climate change through increased temperatures and changes in rainfall patterns. These factors affect feed and water availability, animal health and breeds, and in turn milk production. Warmer and drier conditions increase the likelihood of heat stress in cattle. Heat stress adversely affects reproductive performance in dairy animals (Bruckner, 2018). There is normally a decrease in milk production for cows under heat stress (Bruckner, 2018). Changes in rainfall patterns affects pasture growth patterns thereby affecting the quality and quantity of both feed grains and fodder produced outside dairy areas. Droughts lead to water shortage which in turn leads to a decrease in milk production (Kasulo, et al., 2012).

The low dairy herd productivity in East Africa is attributed to limited use of production technologies and inadequate exploitation of the existing environmental influences. Mapiye et al. (2016) alluded that the low quantity and quality of feed resources affected productivity of dairy animals in sub-Saharan Africa. There is also ample evidence that climate change and variability has an impact on livestock disease prevalence (BCDP, 2013). Gale, et al., (2018) gave three examples of disease outbreaks that are believed to be related to climate change: the unprecedented spread of avian flu; the rapid spread of bluetongue across Europe; and the spread of Rift Valley Fever in parts of Africa which resulted from severe floods. The other consequence of climate change has been highlighted as increased risk that geographically restricted rare breed populations have due to climatic disturbances (Fosu-Mensah, et al., 2010).

Breeding goals may therefore have to be adjusted to account for higher temperatures, lower quality diets and greater disease challenges. Breeds that are well adapted to such conditions may become more widely used (Kasulo, et al., 2012). The study also looks at the changes in rainfall patterns and its impact on water availability, parasite and disease occurrences, pasture production, and milk production within Bungoma County in Western Kenya. The increase in dairy animals is in line with Government's policy in dairy production whose goal is to ensure adequate supply and consumption of milk and milk products. Climate change models paint a bleak picture for Kenya. Global warming is projected to increase temperature by 2 to 3ºC by 2050, with a decline in rainfall and water availability (Fosu-Mensah, et al. 2010). Recent climate change projections over the south eastern Sub-Saharan Africa (including Kenya) predict shorter rainfall seasons associated with a later start to the season, earlier rainfall cessation, increases in mean dry spell length and reductions in rain day frequency (Deressa, et al., 2018).

Climate projections for the period 2010 to 2075 exhibit a decrease in mean cumulative rainfall over most parts of Kenya ranging from -4.8 to -0.7% in annual rainfall changes. The rainfall change is predicted to be worse in some parts of western Kenya but with little

change for most parts of the western Kenya (Deressa, et al., 2018). Indeed other empirical studies have shown that smallholder farmers in Kenya are experiencing changes in climate which is reducing productivity (Mudavadi, et al., 2011). For instance changing rainfall patterns and higher temperatures have led to shorter growing season and farmers are forced to switch from local crop varieties to more expensive hybrid crops (Chase, 2016). These events have led to loss of lives, diminished livelihoods, reduced crop and livestock production, and damaged infrastructure, among other adverse impacts. The torrential rains and severe flooding that were witnessed in the country from March to May 2018, which devastated communities, most of which were already struggling to recover from a prolonged drought, are an example of these events (NCCAP, 2018-2022).

Dairy farming is vulnerable to climate change through increased temperatures and changes in rainfall patterns (Kasulo et al. 2019) and thus affect feed and water availability, animal health and breeds, and in turn milk production. Further, warmer and drier conditions increase the likelihood of heat stress in cattle. There is normally a decrease in milk production for cows under heat stress. Changes in rainfall patterns affects pasture growth patterns thereby affecting the quality and quantity of both feed grains and fodder produced outside dairy areas. Droughts lead to water shortage which in turn leads to a decrease in milk production (Siemes, 2018). Bruckner (2018) indicated that climate change has an impact on the increase or decrease in animal disease risk. Examples of diseases which were related to climate change included avian influenza which spread over 4 continents since the beginning of the new millennium; bluetongue which spread across Europe; and the Rift Valley fever which spread in Africa as a result of severe floods.

3. Methodology

The objective of the study was to determine the impacts of climate change and variability on smallholder dairy cattle production in Bungoma, Kenya. Data were analyzed using both quantitative and qualitative data analyses approaches. Quantitative approach was descriptive, where frequencies and percentages were used. Data from questionnaire were coded with the help of Statistical Package for Social Science (SPSS). The processed data were summarized using tables and figures and presented in frequencies and percentages. The researcher used the thematic analysis method to identify, analyse and report the patterns or themes and other details within the data, as the interpretation of various aspects of the research topic guided by Fowler and Floyd (2000). Correlation analysis was conducted to show the relationship between rainfall (mm), temperature (oC), dairy cattle population and milk production (kgs.) in Mt. Elgon, Tongaren and Kimilili sub counties. The mean score for each of the independent variables was calculated and the Pearson's correlation obtained using SPSS

Secondary information was sourced from published and unpublished sources with literature on the impact of climate change on farming as and with specific focus on smallholder farmers in Bungoma County. These included textbooks, journals, government policy documents, government annual reports on the topic, seminar papers, conference proceedings, business journals, newspapers and periodicals and other relevant literature. Historical metrological data obtained from KNMD was analyzed.

4. Results and Findings

Effect of Climate Change on Milk Production in Bungoma County, Kenya

Small holder dairy farmers' household heads were asked to indicate whether changes in climate had affected their cattle milk production. The results are as shown in Figure 1.

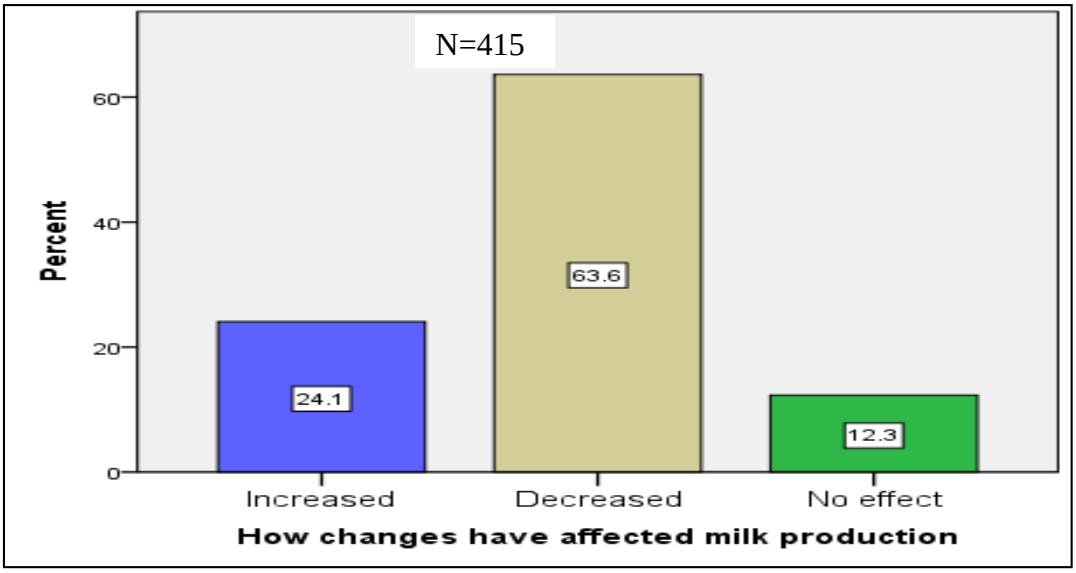


Figure 1: How Climate Changes have Affected Milk Production

Source: Researcher (2019)

From the results, 24.1% respondents indicated that the milk had increased, 63.6% said it had decreased yield while 12.3% indicated that there was no effect. A chi- Square test conducted on the changes in climate indicated that there was a highly significant (<0.01) variation in the responses ($\chi^2_{3,0.00}$=130.943) in changes in climate. Many farmers indicated there has been a decline in milk resulting from climate change effects. Focus group discussions observed that prolonged rainfall experienced in the county has resulted in increased fodder for cattle feeds; however, it has all exacerbated disease causing vectors to multiply rapidly, hence rampant disease outbreaks. In their opinion foot and mouth disease is the most common of all other cattle diseases. This has caused the entire cattle market sector within Bungoma County to be close down. They further, attributed low milk productivity witnessed to poor animal health because of disease infestation.

Dairy production in the county is dependent on weather, which is unpredictable and erratic. This leads to milk production fluctuation with serious decline during drought periods and glut during wet seasons (Bungoma County Government, 2018). Corroborating this finding, Baumgard (2013) confirms that up to 50% drop in milk production in dairy animals is due to reduced feed intake and rest due to metabolic adaptations to heat stress as heat stress response markedly changes post-absorptive nutrient metabolism.

Effect of rainfall variability on production of milk in Bungoma County, Kenya

Further, the study determined whether there was an association between rainfall pattern in the county over the last 15years (2004-2019) and production of milk in liters per cow per year.

Table 1: Effect of rainfall variability on production of milk in Bungoma County, Kenya

			Milk in litres produced per cow per year				Total	Chi square
			Increased	Decreased	Constant	999		
Rainfall pattern in the county last 15years	**Very regular**	Count	1	0	2	0	3	X^2=72.532[a] df=12 p=0.000
		%	33.3%	0.0%	66.7%	0.0%	100.0%	
	Regular	Count	56	47	12	3	118	
		%	47.5%	39.8%	10.2%	2.5%	100.0%	
	Irregular	Count	51	169	28	2	250	
		%	20.4%	67.6%	11.2%	0.8%	100.0%	
	Very irregular	Count	0	0	1	0	1	
		%	0.0%	0.0%	100.0%	0.0%	100.0%	

	999	Count	2	0	0	1	3	
		%	66.7%	0.0%	0.0%	33.3%	100.0%	
Total		Count	110	216	43	6	375	
		%	29.3%	57.6%	11.5%	1.6%	100.0%	

Source: Researcher (2019)

Table 1 summarizes results of chi-square test carried out. The findings show that there was a statistically highly significant ($p<0.01$) relationship between rainfall pattern in the county over last 15years (2004-2019) and production of milk in liters per cow per year. According to the Director of livestock and fisheries development of Bungoma County, this increase in milk production may be attributed to a number of factors; i.e. farmers motivated by good milk prices, improved breeding selection, improved extension services and increased pastures due to increased rainfall in the county. Respondents were asked to give their views regarding the effects of the changes in the rainfall pattern on the availability of pasture in this sub-county. The results were recorded in Figure 2.

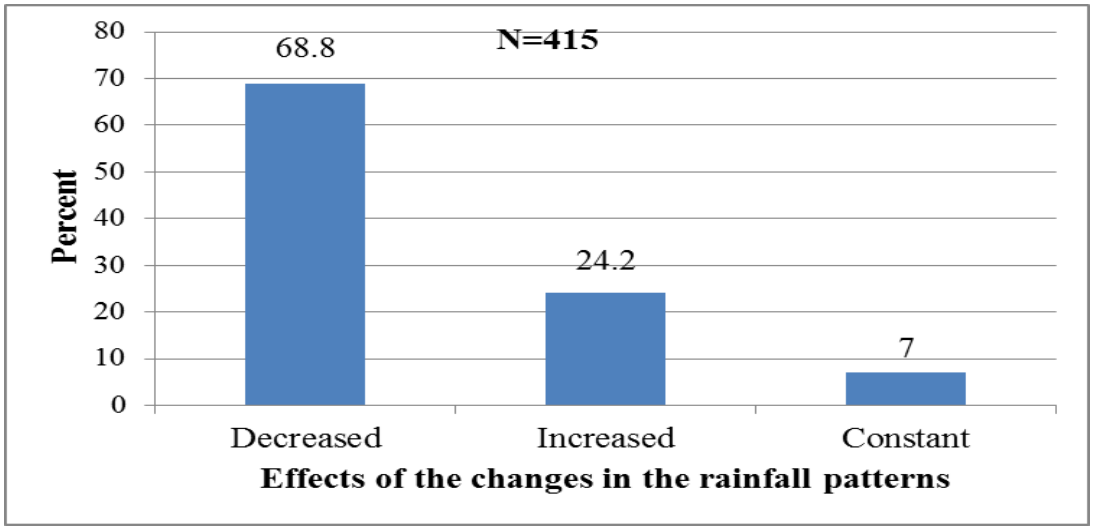


Figure 2: Effect of rainfall variability on pasture in Bungoma County, Kenya

Source: Researcher (2019)

From the results, 68.8% indicated that the amount of pasture had decreased, 24.2% indicated that it had increased while 7.0% indicated that it was constant. The observed decrease in pastures could have been occasioned by various factors, climate change and weather variability, increase in numbers of livestock to cushion adverse climatic effects or normal scramble of scare land resource utilisation i.e. population pressure for settlement, cash crop and food crop needs. More importantly, food security seems to hold priority position in land use allocation said key informers. There is a highly statistically significant ($p=0.01$) relationship between rainfall patterns and milk production. This is because the calculated ($\chi^2_{3,0.00}$=32.320) is greater than the critical χ^2_2 which is 15.507. In addition, the p-value (0.000) is less than the significant level (0.05). The results recorded from the smallholder dairy cattle farmers indicated that rainfall was significantly decreasing and very unpredictable over the last fifteen years. They further observed that the county is becoming drier and facing water shortages for dairy farming and crop cultivation.

Effect of Climate Change on Dairy Cattle Milk and Crop Pest Infestation in Bungoma County, Kenya

Small holder farmers were asked to indicate their level of agreement on whether or not climate change had led to crop pest infestation. The results were recorded in Figure 3.

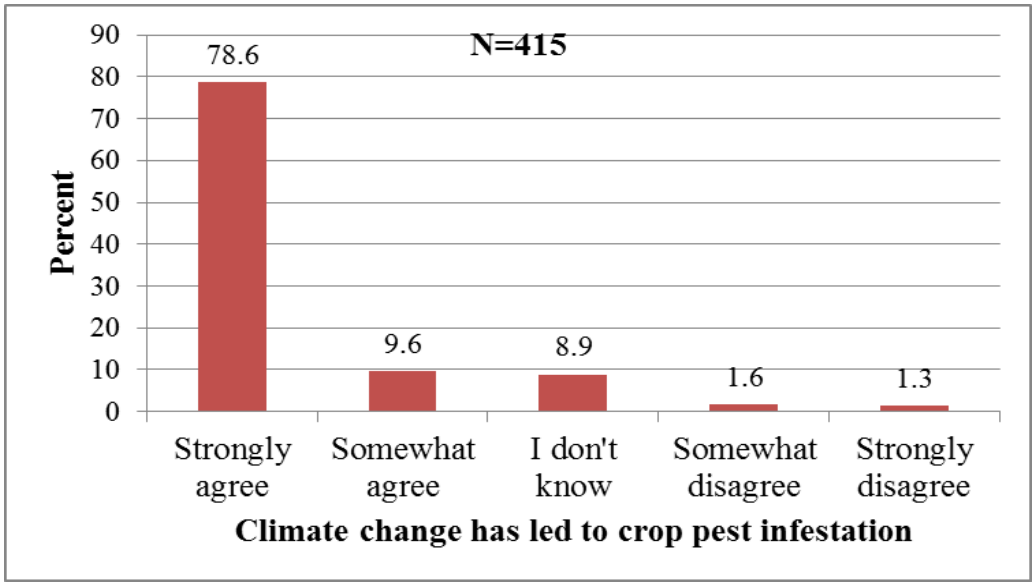


Figure 3: Effect of Climate change on crop pest infestation in Bungoma County, Kenya

Source: Researcher (2019)

Majority (78.6%) strongly agreed, 9.6% somewhat agreed, 8.9% didn't know, 1.6% somewhat disagreed while 1.3% strongly disagreed that climate change has exacerbated crop pest infection. Chi square test indicated a significant relationship ($p<0.01$) between climate change and milk production as shown by as shown by a calculated $\chi_2^2 = 68.094$ which is greater than the critical $\chi_2^2 = 51.106$. Further, the p-value (0.000) was less than the significance level (0.05). This finding collaborates with Gautam *et al.,* (2013) and West *et al.*, (2015), that plant diseases are also estimated to cause up to a 20 per cent reduction in the yield of principal food and cash crops worldwide. In agreement, Abang *et al.* (2014), noted that aphids are the most recurrent insect pests in vegetable crops. In Focus group discussions a participant stated that;

> "the re-occurrence of *Chikhungu* (meaning armyworms in local language) has resulted in perennial crop failure and losses."

Climate Change on Food and Dairy Cattle Milk production in Bungoma County, Kenya

As to whether crop production has been affected by climate change, the results were recorded in Figure 4.

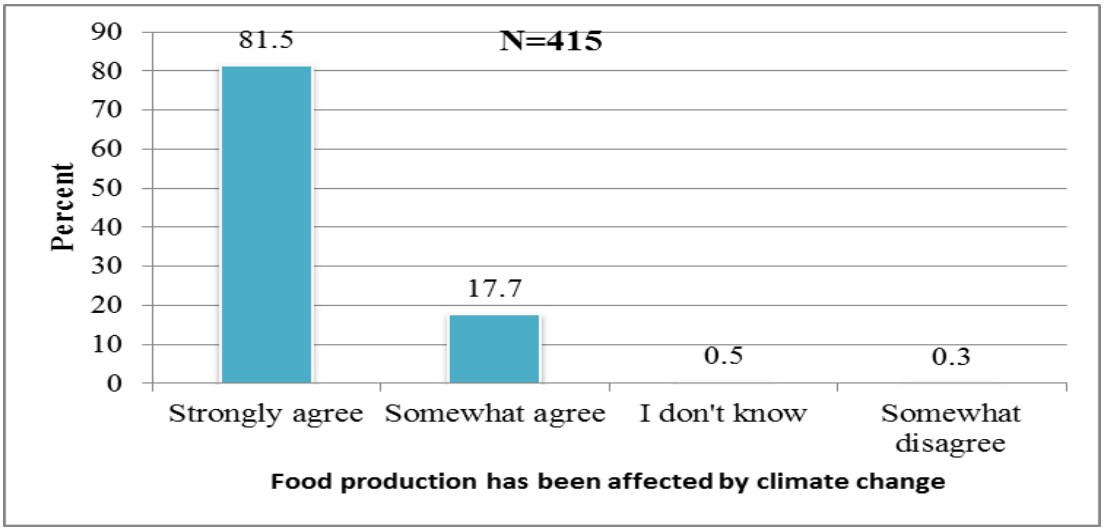


Figure 4: Climate Change and Food production in Bungoma County, Kenya

Source: Researcher (2019)

From the results, 81.5% strongly agreed, 17.7% somewhat agreed, 0.5% did not know, 0.3% somewhat disagreed. Chi square test indicated a significant relationship ($p<0.01$) between food production and milk production as shown by as shown by a calculated χ_2^2 = 55.08 which is greater than the critical χ_2^2 = 42.425. Further, the p-value (0.000) was less than the significance level (0.05). The result is in agreement with Zagst (2011) who asserted that farmers experiencing frequent droughts, excessive rains in the wet season and subsequent crop failures and decline in livestock productivity which increases their vulnerability to food insecurity and poverty. Also, a study done on food security in Bungoma County by Muyesu (2013) revealed that households do not access sufficient food for their dietary requirements.

Effect of Climate change on Cost of food and Dairy Cattle Milk in Bungoma County, Kenya

As to whether the cost of food is increasing because of climate change, the results were recorded in Figure 5.

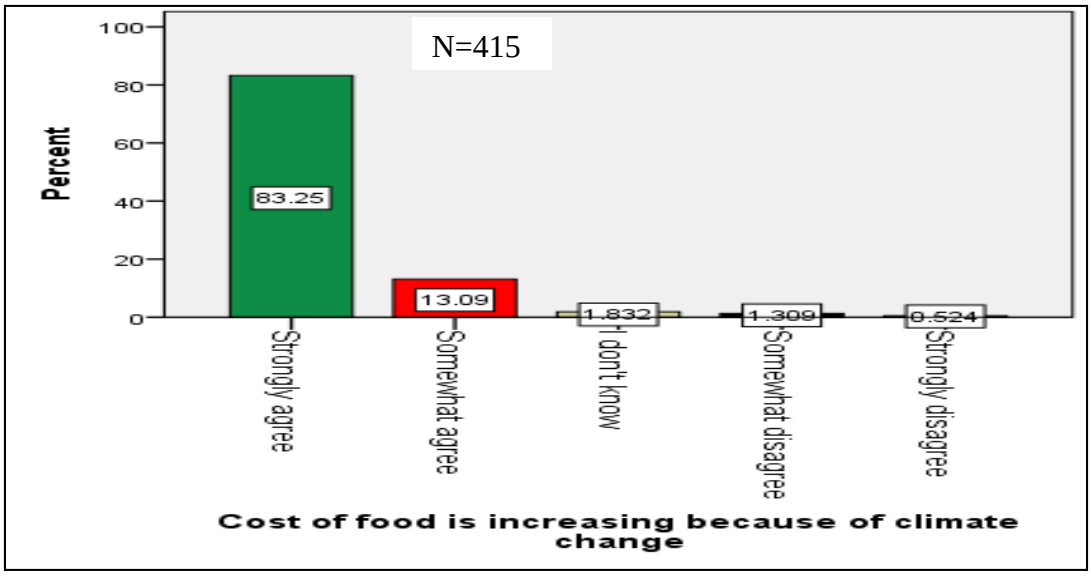


Figure 5: Climate Change influencing Cost of food in Bungoma County, Kenya.

Source: Researcher (2019)

From the results, 83.25% strongly agreed, 13.09% somewhat agreed, 1.8% did not know, 1.3% somewhat disagreed while 0.5% strongly disagreed. Chi square test indicated a significant ($p<0.01$) relationship between cost of food and milk production by a p-value (0.000) which was less than the significance level (0.05). Key informant interviews and Focus group discussions said that there was a close relationship between climate change effects and food prices. Crop failure resulting from adverse effects of climate change, is mated with hikes in food price. The results concurs with Barriopedro *et al*. (2011), Watanabe *et al*. (2013) and Hoag (2014) that 2010–2011 food price spike was initially triggered by the exceptional heat in summer 2010, with an extent from Europe to the Ukraine and Western Russia. Mann *et al*. (2017) confirms that there is evidence that these effects were both linked and made more likely through climate change. .

Relationship between frequency of drought and the quality of calves delivered in Bungma County, Kenya

Further, the study sought to determine the relationship between the frequency of experiencing drought and the quality of calves delivered per cow. The results were as shown in Table 2.

Table 2: Relationship between frequency of drought and the quality of calves delivered per cow

			Number and quality of calves delivered per cow				Total	Chi square
			No reduced and quality decreased	No increased and quality improved	No change, don't know	999		
Frequency of experiencing droughts	Very often	Count	26	5	0	0	31	X^2=319.031[a]
		%	83.9%	16.1%	0.0%	0.0%	100.0%	df=9
	Often	Count	101	13	5	0	119	p=0.000
		%	84.9%	10.9%	4.2%	0.0%	100.0%	
	Rarely	Count	97	37	17	1	152	
		%	63.8%	24.3%	11.2%	0.7%	100.0%	
	999	Count	5	4	1	57	67	
		%	7.5%	6.0%	1.5%	85.1%	100.0%	
Total		Count	229	59	23	58	369	
		%	62.1%	16.0%	6.2%	15.7%	100.0%	

Source: Researcher (2019)

As indicated in the Figure 5.19, there is a statistically significant relationship between the frequency of experiencing drought and the quality of calves delivered per cow. This is because the calculated χ_2^2 = 319.031 is greater than the critical χ_2^2 which is 297.956. In addition, the p-value (0.000) is less than the significant level (0.05). Key informant interviews and Focus group discussions stated that increased drought experiences leads to decrease in the quality of calves due to inadequate, imbalanced nutritional quotient of feeds provided to the cattle during gestation. In some cases, calves growth curve shows stagnation. The growth of such calves is seriously endangered as they are prone disease infection and slow recovery process. These findings concurs with those of Herrero, *et al* (2010) who established that increased drought frequencies to more than a drought every five years could cause significant, irreversible decreases in livestock numbers and hence the milk production in arid and semi-arid areas. Odhiambo *et al.* (2019) argues that milk production declines during droughts; this has led to an increase in calf pneumonia and increasing cases of silent heat due to poor management.

Effect of Drought on Amount of Milk Produced Per Cow in Bungoma County, kenya

Respondents were asked to state how the changes had on the amount of milk produced per cow. The results were recorded in Figure 6.

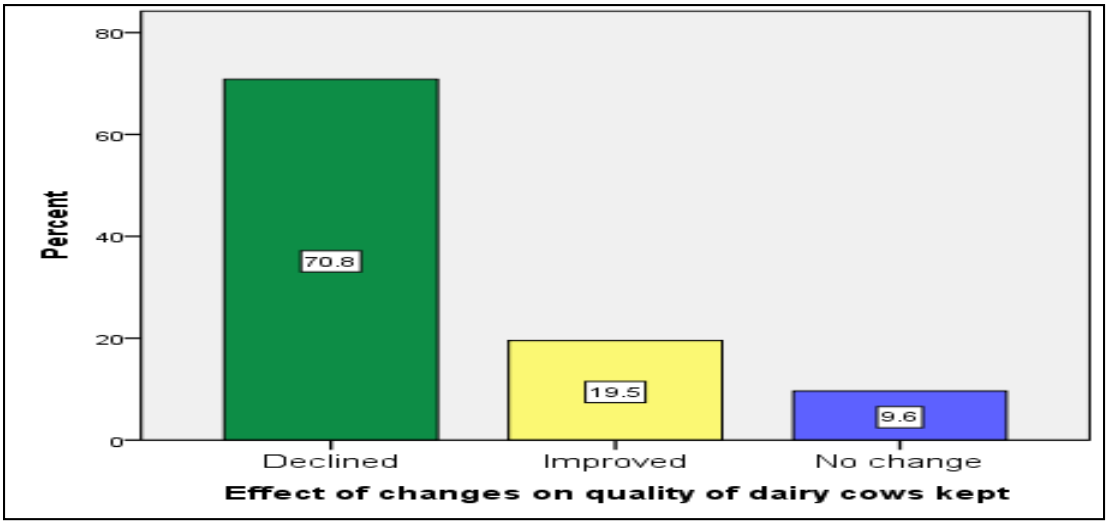


Figure 6: Effect of changes on quality of dairy cows kept

Source: Researcher (2019)

From the results, 70.8% respondents indicated that the quality had declined, 19.4% said it had improved while 9.8% indicated that the quality had not changed. A significant 70.8% observed a decline in the quality of cows kept. Corroborating this finding Samir (2017) argues that for the solution of adaptation problems it is important to know the qualitative and quantitative responses of the animal to various degrees of heat stress; Promoting indigenous breeds for rearing as these are more heat tolerant than cross bred and exotic breeds.

The small scale dairy cattle farmers were asked questions on breeding and calving whose descriptive statistics were summarized in Table 3.

Table 3: Descriptive statistics on breeding and calving in Bungoma County, Kenya

	N	Minimum	Maximum	Sum	Mean	Std. Error	
Number of cows and heifers that bed last season	342	0	6	542	1.58	0.0576	Chi square X^2=319.031a
Number of those that became pregnant	373	0	6	523	1.40	0.0501	df=6
Number that successfully calved	369	0	6	466	1.26	0.0496	p=0.000
Number that aborted	280	0	1	13	.05	0.0126	
Number that had still births	275	0	2	37	.13	0.0219	
Number that died soon after calving	276	0	6	25	.09	0.0278	
Valid N (list wise)	257						

The data shows that farmers had several challenges associated with breeding. Some failed to get pregnant after breeding, some aborted, had still births or calves died soon after delivery. The calculated Chi-square χ_2^2 = 319.031 was greater than the critical 434.507. In addition, the p-value (0.000) is less than the significant level (0.05). This finding agrees with Odhiambo *et al*., (2019) and Maleko *et al*., (2018) that the effects of climate change has compromised the breeding of the dairy cattle, thereby elongating the calving interval. Focus group discussions added their voice, that breeding has increasing become unpredictable characterised by miscarriages and calving difficulties.

Pearson Correlation Analysis and Regression between rainfall pattern, temperature, dairy cattle and milk production for Bungoma County, period (2003-2018).

Correlation analysis was conducted to show the relationship between rainfall (mm), temperature (oC), dairy cattle population and milk production (kgs.) in Mt. Elgon, Tongaren and Kimilili sub counties. Data for three types of cattle was collected from all the sites under consideration namely Kimilili, Tongaren and Mt. Elgon. These regions have different types of cattle that are kept for dairy purposes.

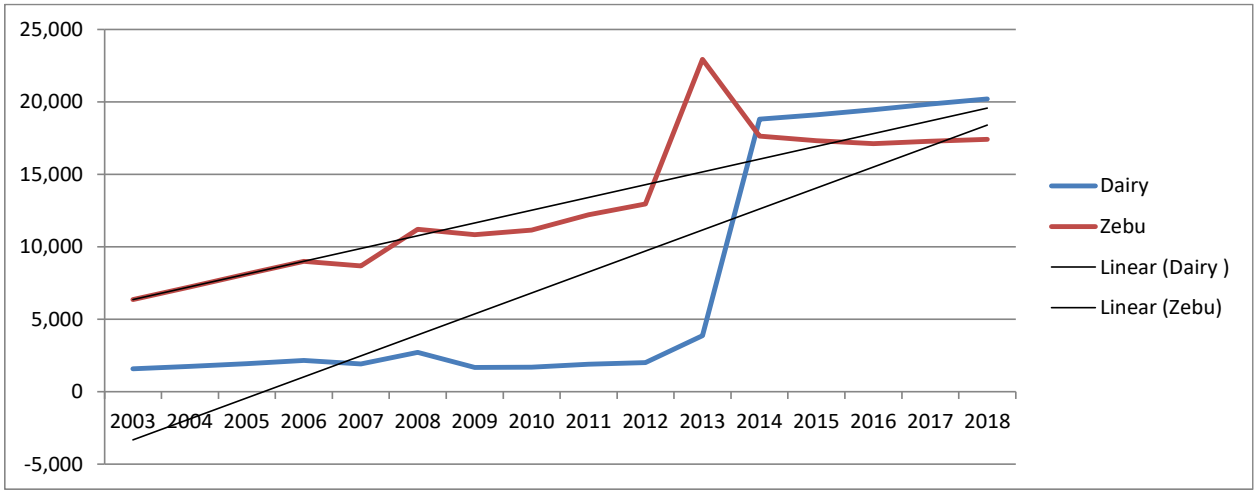
4.8.1 Correlation Analysis for Kimilil

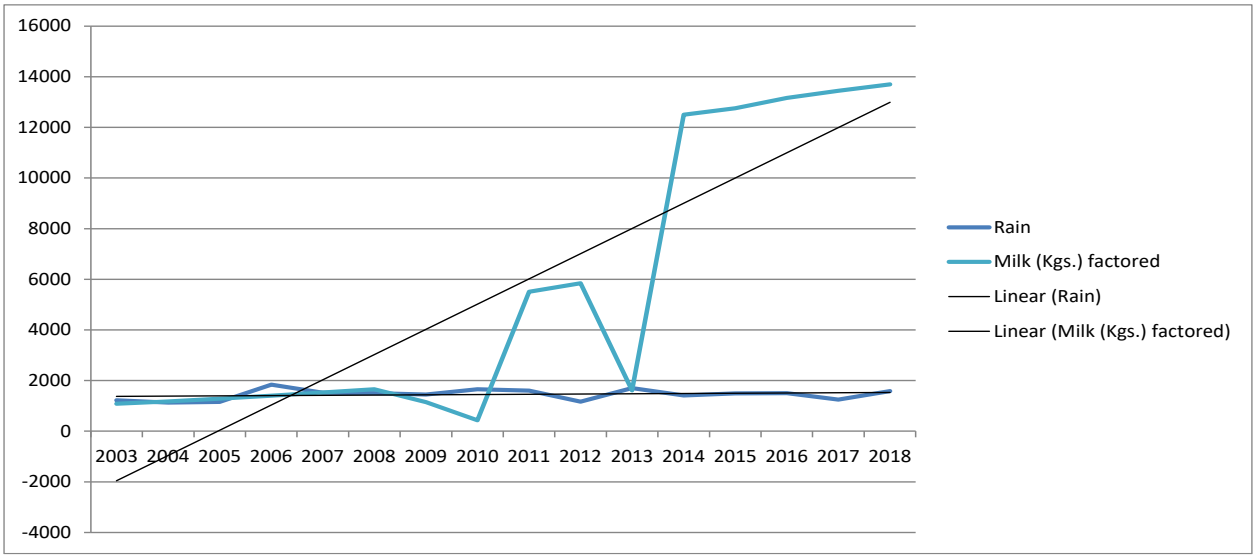
Correlation was done on data from Kimilil from the year 2003-2018 which had the most accurate and complete set of data for all the parameters under consideration. The results of the correlation are illustrated in Table 4.

Table 4: Correlation Analysis for Zebu, Dairy and Rain from 2003-2018 in Kimilil

Correlation (Rain vs Dairy cattle)	Correlation (Rain vs Zebu cattle)	Correlation (Rain vs Milk)	Correlation (Dairy cattle vs Milk)	Correlation (Zebu cattle vs Milk)
0.021679729	0.315947395	-0.037594073	0.960741186	0.663088805

The results indicated that there is positive correlation between the rainfall over the years and the population of cattle within the region. This indicates that as the annual rainfall has been increasing, so has the population of both the Zebu and dairy cattle with Zebu exhibiting a stronger correlation. The correlation trend of Zebu, Dairy and Rain from 2003-2018 are as shown in Figure 7.





The correlation between both cattle types and total milk production is strongly positive as hypothesized. As the cattle increased so did the milk production. There was however negative correlation between the rainfall and the milk production by the two cattle breeds. The correlation is quite low and as such may not tell us much about the relationship. The reason for the negative correlation could be that the milk production is increasing at a very high rate compared to the rainfall which is indicating and overall increasing trend but is characterised by high variability.

Correlation Analysis for Tongaren

Correlation was done on data from Tongaren from the year 2003-2018 which had the most accurate and complete set of data for all the parameters under consideration. The results of the correlation are illustrated in Table 5.

Table 5: Correlation Analysis for Zebu, Dairy and Rain from 2003-2018 in Kimilili

Correlation (Rain Vs Dairy Cattle)	Correlation (Rain Vs Zebu Cattle)	Correlation (Rain Vs Milk)	Correlation (Dairy Cattle Vs Milk)	Correlation (Zebu Cattle Vs Milk)
0.323962945	-0.4114622	0.312891063	0.831186205	-0.08966167

From analysis there was relatively strong positive correlation between the rainfall amounts across the years and the population of Dairy cattle indicating that as the rainfall increased and the dairy cattle population likewise increased as shown in Figure 8 on the correlation trend for rain, dairy and Milk from 2003-2018 for Tongaren.

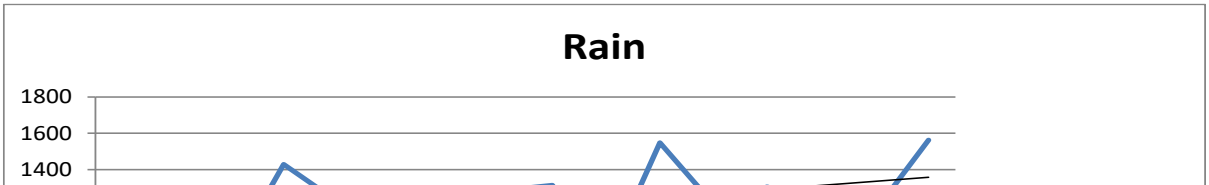


Figure 8: Trend of Rain, dairy and Milk from 2003-2018 for Tongaren

There was negative correlation between rainfall amounts across the years and the population of Zebu cattle. Therefore as the rainfall increased the Zebu cattle population decreased. There was also strong positive correlation between rainfall and milk production for the region which is unlike the situation observed for Kimilili. This therefore indicates that as the rainfall increased so did the milk production for the cattle in Tongaren. Lastly, there was also a very strong correlation between the milk production and the dairy cattle

and a negative one between the milk production and Zebu cattle. This indicates that the dairy cattle were mostly responsible for the increase in milk production across the years for the region.

Correlation Analysis for Tongaren

Correlation was done on data from Tongaren from the year 2003-2018 which had the most accurate and complete set of data for all the parameters under consideration. The results of the correlation are illustrated in Table 6.

Table 6: Correlation Analysis for Zebu, Dairy and Rain from 2003-2018 in Kimilili

Correlation (Rain Vs Dairy Cattle)	Correlation (Rain Vs Zebu Cattle)	Correlation (Rain Vs Milk)	Correlation (Dairy Cattle Vs Milk)	Correlation (Zebu Cattle Vs Milk)
-0.067250071	-0.188737315	0.239447778	0.56723892	0.261039249

There was negative correlation between rainfall and both cattle populations across the years. The rainfall exhibited an average increase across the years from 2003 as shown by figure (xx) while still having variability. Figure (xy) shows a plot of both cattle populations across the years along with their trend lines. The average increase in Zebu cattle is quite small and is characterised by significant variability, this could explain why the correlation is very small (0.06725) and negative. The relationship between cattle population and milk production as highlighted by the correlation is positive for both cattle breeds, such that as the population increases so does the milk production. There's also a positive correlation between rainfall and milk production (0.26) which indicates that as the rainfall has been increasing across the years, so has the milk production. The correlation trend for the Zebu, Dairy and Milk from 2003-2018 for Tongaren is illustrated in Figure 9.

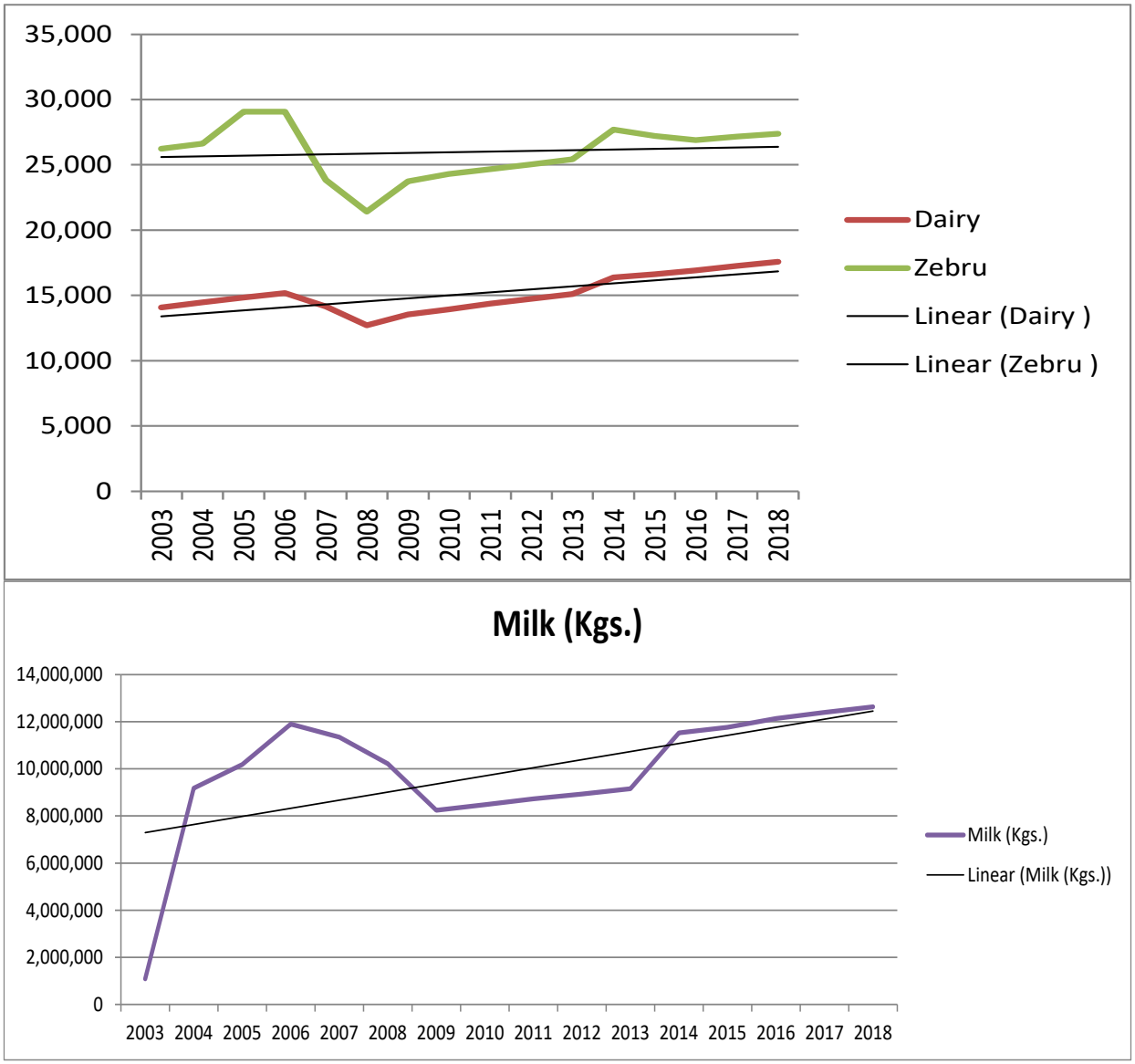


Figure 9: Trend of Zebu, Dairy and Milk from 2003-2018 for Tongaren

Table 7: Pearson Correlation Analysis between milk Production, rainfall pattern, temperature and dairy cattle population in Bungoma County, Kenya

	Correlations						
	Milk production	**SE**	**Rainfall**	**SE**	**Temperature**	**SE**	**Dairy cattle population**
Milk production (kgs.)	1.000						
Rainfall(mm)	0.108	0.0034	1.000				
	0.005						
Temperature (°C)	-0.289	0.0027	0.114	0.0047	1.000		

	0.046		0.440			
Dairy cattle				0.0064	0.0037	
population	.679**	0.0035	0.127	0.193		1.000
	0.000		0.388	0.188		

The results indicated that rainfall (mm) was positively and significantly ($p<0.01$) associated to milk production. However, temperature (^oc) was negatively and significantly associated to milk production (kgs.). Lastly, the dairy cattle population was positively and significantly ($p<0.01$) associated to milk production (kgs.). This implied that the increase in Rainfall (mm) and Dairy cattle population had an increasing effect on Milk production (kgs.). However, an increase on temperature (^oC) had a decreasing effect on Milk production (kgs.). The increase in milk level can be attributed to the increase of the dairy cattle population in Bungoma County as tabulated in 2.1 where there were 125,510 dairy cattle in 2014, 127,421 dairy cattle in 2015, 129,758 dairy cattle in 2016, 132,354 dairy cattle in 2017 and 134,736 dairy cattle in 2018. However, the production in comparison to the increased dairy cattle thus does not portray significant increase in milk production but increase in dairy cattle population. Rodriquez *et al.,* (2015) on the effects of relative humidity, maximum and minimum temperature, pregnancy and stage of lactation on milk composition and yield reported with a decrease of milk yield when the drought seasons prolonged.

The regression analysis was conducted to depict the statistical relationship between milk production with the input of type of cattle, rainfall and temperature.

Table 8: Regression Analysis on Milk productivity and Type of Cattle, Rainfall and Temperature

Milk	**Coef. ±SE**	**t**	**P>|t|**	**[95% Conf.**	**Interval]**
Dairy	700 ±118	5.940	0.000	462	938
Zebu	-151 ±174	-0.870	0.390	-503	200
Rain	6099 ±3518	1.730	0.090	-1000	13198
Tmax	-81259 ±1073	-0.080	0.940	-2247582	2085064
Tmin	-108751 ±1128	-0.100	0.924	-2387046	2169545
_cons	-4600366 ±1660	-0.280	0.783	-38200000	29000000
F(3, 44)	= 16.43				
Prob > F	= 0.000				
R-squared	= 0.5284				
Adj R-squared	= 0.4962				

The results indicated that the dairy cattle (Exotic breed) ($\beta=700$, $p=0.000<0.05$) had a positive and significant ($p<0.05$) relationship with milk production. The Zebu cattle (Local breed) ($\beta=-151$, $p=0.390>0.05$) had a negative and non-significant ($p>0.05$) relationship with milk production. The amount of rainfall ($\beta= 6099$, $p=0.090>0.05$) had a positive but insignificant ($p>0.05$) relationship with milk production. The level of temperature for Tmax and Tmin ($\beta= -108751, -4600366$, $p=0.940, 0.924>0.05$) had a negative and insignificant relationship with milk production. These findings are in line with those of Mukherjee, *et al., (*2013) who found that dairy cows need an optimum range of atmospheric conditions and not more than 18.3^oC to be most productive. The scholars also established that future productivity growth in dairy farming can be hampered by a warmer environment in the region. The findings also in line with those of Zewdu *et al*. (2014), who noted that variability in climate influenced the production in milk, such that; as temperature increased, milk production declined notably.

Warmer and drier conditions increase the likelihood of heat stress in cattle. Heat stress adversely affects reproductive performance in dairy animals (Zewdu *et al.* 2014). The general increase in temperature leads to cattle heat stress that may affect the health of the animal and milk productivity. Summer *et al.* (2019) point out the negative effects of heat stress on the composition of milk (organic and inorganic components) and describe how those changes are strongly associated with the alteration of cheese making properties and the merchandise value of milk. The effect of climate change on health and growth, reduce body weight, reduce body condition score, reduce average daily body gain, reduce feed intake, and reduce feed conversion and allometric measurements (Zewdu *et al.* 2014). Bungoma County annual temperature range from - 0°c and 32°c due to different levels of attitude. Therefore, cases of heat stress may be witnessed in the county. Heat distress suffered by animals will reduce the rate of animal feed intake and result in poor growth performance (Rowlinson, 2018).

5. Conclusions

The finding indicates that there was decreasing acreage under fodder and pasture production. Farmers owned less than 5 dairy cows that produced a daily average of 5-8 litres and 2-5litres per cow during the wet and the dry season respectively. During the dry season, farmers used preserved feed, crop residues or feeds purchased from neighbours. While the tick borne diseases, pneumonia and lumpy skin incidences had increased in the county, foot and mouth disease had decreased during the past ten years. Extreme weather changes especially dry spell was associated with increased incidences of tick borne and Foot and Mouth diseases, shortage of feed resources and reduced milk production in the three study sites

Changes in climatic patterns especially the decreasing dry spell, droughts, and unpredictable precipitation has contributed to increased livestock diseases incidences e.g East coast fever, foot and mouth diseases, shortage of feed resources hence, increased cost of food and feeds, and overall reduction of milk production in the Bungoma County. Therefore, there existed a significant relationship between the changing climatic patterns and smallholder dairy herd productivity in the county.

Climate change and variability effects are on great increase and quickly eroding the gains of dairy technologies adapted in the recent times in the county to boost smallholder dairy cattle production in the county. Both Policy formulation and investment adaptations by the county government to address to minimize losses and damages incurred by smallholder dairy cattle farmers, occasioned by increased frequency of extreme rainfall over the three sites.

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